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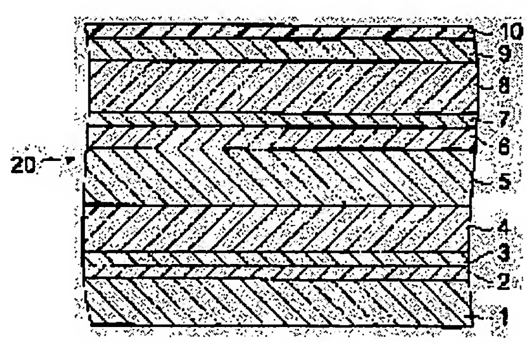
(54) PERPENDICULAR MAGNETIC RECORDING MEDIUM

(57)Abstract:
PROBLEM TO BE SOLVED: To obtain a perpendicular magnetic recording medium wherein magnetization is not attenuated by an external magnetic field and which has a stable signal and is nearly free from noise even when recording and reproduction are repeated.

SOLUTION: The perpendicular magnetic recording medium has at least a substrate, a Co alloy bias layer, a soft magnetic layer and a magnetic recording layer which are laminated. In the Co alloy bias layer, the direction of its residual magnetization is directed in one direction of its radial directions and tsoft is 40 nm-200 nm. The magnetic recording medium satisfies the formula Mssoft × (tsoft-40 nm)>Mssoft × 40 nm+Msbias × tbias. (tbias, Msbias, tsoft and Mssoft denote the thickness of the Co alloy bias layer, its saturation magnetization, the thickness of the soft magnetic layer and its saturation magnetization, respectively).



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CLAIMS

[Claim(s)]
[Claim 1] Nonmagnetic substrate The cobalt alloy bias layer prepared on this nonmagnetic substrate The soft-magnetism layer which is prepared in this cobalt alloy bias layer, and makes iron or cobalt a principal component Vertical-magnetic-recording layer It is the vertical-magnetic-recording medium equipped with the above. this cobalt alloy bias layer The direction of the residual magnetization is suitable in the one direction of radial [the]. This cobalt alloy bias layer thickness tbias, The saturation magnetization Msbias, this soft-magnetism layer thickness tsoft, and its saturation magnetization Mssoft Following formula Mssoftx(tsoft-40nm) >Mssoftx40 nm+Msbiasxtbias, however this soft-magnetism layer thickness tsoft are characterized by filling **** with 40nm or 200nm.
[Claim 2] The aforementioned soft-magnetism layer thickness tsoft is a vertical-magnetic-recording medium according to claim 1 characterized by being 40nm or 150nm.
[Claim 3] The aforementioned cobalt alloy bias layer is 160000. Vertical-magnetic-recording medium according to claim 1 characterized by having the coercive force Hc more than A/m.
[Claim 4] the ratio of the radial residual magnetization Mr of the aforementioned cobalt alloy bias layer and the aforementioned soft-magnetism layer, and saturation magnetization Ms -- the vertical-magnetic-recording medium according to claim 1 characterized by Mr/Ms being 0.97 or more

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[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] this invention relates to the vertical-magnetic-recording medium which uses perpendicular direction magnetization especially among the magnetic-recording media used for a hard disk drive unit etc.
[0002]
[Description of the Prior Art] As compared with the magnetic-recording layer within a field, the vertical-magnetic-recording layer which can record the direction of a line is [in a thick record layer] stronger than the magnetic-recording layer within a field to heat fluctuation resistance at high density. According to the interaction of a head and a soft-magnetism layer, since ideal vertical recording is made, especially the perpendicular bilayer film medium that prepared the soft-magnetism layer of high permeability in the bottom of the record layer which has a perpendicular magnetic anisotropy can respond to future twist high-density record. However, even if, if such a soft-magnetism layer is prepared in a record medium, even if it is weak external magnetization, magnetization of a soft-magnetism layer changes easily during disk rotation, and it is known that a fall and noise of a record signal will occur.
[0003] In order to improve change of magnetization of such a soft-magnetism layer, the thing which prepared the antiferromagnetism layer in JP,03-53686,B on the soft-magnetism layer, or the thing which prepared the permanent magnet layer in the bottom of a soft-magnetism layer at JP,7-105027,B is indicated. Moreover, arranging the sense of magnetization of a permanent magnet layer with radial is also indicated in this case. Giving an anisotropy to a soft-magnetism layer radial becomes the mechanism in which magnetization change of the circumferencial direction of a soft-magnetism layer is caused by magnetization rotation, and it is thought that the effect which the responsibility in a RF also makes good arises. Furthermore, what considered these as laminating composition is indicated, and it is indicated that artificial grid systems, such as CoFe/Cu, can be used as a bias layer for impressing bias to a change of an antiferromagnetism layer.
[0004] However, these bias layers [like] are premised on a weak ground magnetic field. In order that an external magnetic field may make an external magnetic field intercept in a soft-magnetism layer and may press down reversal of a bias layer to the actual equipment from which thousands A/cm may be reached, it is indicated by JP,10-283624,A in soft-magnetism thickness that 600nm or more is required.
[0005] Thus, soft-magnetism thickness was considered that the stability to an external magnetic field and the point of a power efficiency are sufficient as thickening until now. However, a magnetic domain enters even into a data area and taking a spike noise in the place where an anti-magnetic field becomes strong like [the periphery section of a disk and near the inner circumference section of a disk], since generating of a magnetic domain cannot be pressed down, although generating of a magnetic domain can be suppressed in the inside periphery of a disk, if soft-magnetism thickness is thick cannot be finished. Moreover, if soft-magnetism thickness is thick, although stopped, since a reverse magnetic domain occurs in a soft-magnetism layer easily, reversal of bias has led to increase of a noise. Therefore, it migrated to the whole disc data field, and there was no generating of a magnetic domain until now, it was stable also to the external magnetic field, and the small medium of a noise has not been realized.
[0006]
[Problem(s) to be Solved by the Invention] Even if the purpose of this invention repeats record reproduction by the external magnetic field, without magnetization declining, its signal is stable, and it is to offer a vertical-magnetic-recording medium with few noises.
[0007]
[Means for Solving the Problem] The cobalt alloy bias layer which was prepared on the nonmagnetic substrate and this nonmagnetic substrate according to this invention, It is a vertical-magnetic-recording medium possessing the soft-

magnetism layer which is prepared in this cobalt alloy bias layer, and makes iron or cobalt a principal component, and a vertical-magnetic-recording layer. this cobalt alloy bias layer The direction of the residual magnetization is suitable in the one direction of radial [the]. This cobalt alloy bias layer thickness tbias, The saturation magnetization Msbias, this soft-magnetism layer thickness tsoft, and its saturation magnetization Mssoft Following formula Mssoftx(tsoft-40nm) >Mssoftx40 nm+Msbiasxtbias, however the vertical-magnetic-recording medium characterized by this soft-magnetism layer thickness tsoft filling **** with 40nm or 200nm are obtained.
[0008]
[Embodiments of the Invention] In the vertical-magnetic-recording medium by which this invention has a nonmagnetic substrate and a vertical-magnetic-recording layer Between a nonmagnetic substrate and a vertical-magnetic-recording layer, the soft-magnetism layer which makes a principal component the cobalt alloy bias layer and iron, or cobalt radial [the] with which the direction of the residual magnetization has turned to ** on the other hand is prepared. And when Msbias and this soft-magnetism layer thickness are set to tsoft and the saturation magnetization is set [cobalt alloy bias layer thickness] to Mssoft for tbias and its saturation magnetization, Following formula Mssoftx(tsoft-40nm) >Mssoftx40 nm+Msbiasxtbias is filled, and soft-magnetism layer thickness tsoft is characterized by being 40nm or 200nm.
[0009] Since the whole data area of strength and a vertical-magnetic-recording medium is not made to generate a reverse magnetic domain for a bias magnetic field by preparing the cobalt alloy bias layer radial [the] in which the direction of the residual magnetization has turned to ** on the other hand between the nonmagnetic substrate of a vertical-magnetic-recording medium, and a soft-magnetism layer according to this invention, generating of a spike noise can be suppressed. Furthermore, the noise from a bias layer can be effectively intercepted by the soft-magnetism layer by specifying the relation between this cobalt alloy bias layer, soft-magnetism layer thickness, and saturation magnetization.
[0010] If the direction of residual magnetization is not suitable in the one direction of radial [the], a reverse magnetic domain will occur in a soft-magnetism layer, and it will become the cause of a spike noise.
[0011] Furthermore, if the relation between a cobalt alloy bias layer, soft-magnetism layer thickness, and saturation magnetization does not fill the above-mentioned formula, the magnetic field which magnetization distribution of a bias layer generates will reach to a head, and will serve as a noise.
[0012] Here, unlike a soft-magnetism layer, a cobalt alloy bias layer says the layer for on the other hand impressing Mukai's magnetic field to a soft-magnetism layer. The material into which a magnetic field has the property within a field that on the other hand reversal of a magnetic field does not take place easily toward Mukai is chosen as this. As such a material, CoPt, CoCrPt, CoCrTa, CoCrPtTa, CoCrPtTaB, CoPtO, CoPtCrO, CoNiPt, CoNiPtCr, CoSm, FePt, etc. can be used.
[0013] A cobalt alloy bias layer is 160000 preferably. It has the coercive force Hc more than A/m.
[0014] moreover, the ratio of the radial residual magnetization Mr of a cobalt alloy bias layer and a soft-magnetism layer, and saturation magnetization Ms -- it is desirable that Mr/Ms is 0.97 or more Thus, a noise can be further reduced by suppressing magnetization distribution of a cobalt alloy bias layer.
[0015] The bias magnetic field to the soft-magnetism layer given by the bias layer is decided in the state of the switched connection of the interface of a bias layer and a soft-magnetism layer. It is expressed with gamma=HaxMssoftxtsoft when energy per unit surface area in this interface is set to gamma (erg/cm2).
[0016] The graphical representation which expresses the relation between soft-magnetism layer thickness and a bias magnetic field to drawing 1 is shown.
[0017] Among drawing, when 101 use CoCrPtTaB as CoZrNb and a Co alloy bias layer as a soft-magnetism layer and CoPtCrO is used for 102 as CoFe and a Co alloy bias layer as a soft-magnetism layer, 103 expresses respectively the graph at the time of using CoCrPt as FeCoN and a Co alloy bias layer as a soft-magnetism layer. Moreover, it is square, and when CoPt is used for the point expressed as CoZrNb and a Co alloy bias layer as a soft-magnetism layer, the point expressed with ** shows respectively the case where Co is used as CoZrNb and a Co alloy bias layer as a soft-magnetism layer.
[0018] When Co alloy is used as a bias layer as a soft-magnetism layer, using Fe and Co as a principal component, it is a bias magnetic field 1580 While making it larger than A/m and making it a magnetic domain wall not start the data area of a magnetic-recording medium 1580 Even if the magnetic field of A/m is impressed, in order to make it residual magnetization not fall, it is effective to make 200nm or less of thickness of a soft-magnetism layer for it to be desirable and smaller than 150nm at least. If this thickness is thinner than 200nm, though a magnetic domain wall will be looked at by the periphery section and the inner circumference section of a medium, a magnetic domain wall does not start even a data area. Moreover, if thinner than 150nm, a magnetic domain will not be seen all over a medium, but it is 1580. Even if it impresses the magnetic field more than A/m, residual magnetization reverts to the state of a basis.

[0019] As mentioned above, it is effective to make 200nm or less of soft-magnetism layer thickness for it to be desirable and thinner than 150nm by the perpendicular bilayer film medium. Since it was such, it turns out that artificers produce the medium by which a soft-magnetism layer is 120nm, and set the bias layer to 150nm, and a complicated noise rides on an actual reproduction wave when [the] W/R evaluation is carried out. Probably because the bias layer has reversed this cause by the magnetic field of a recording head, although not generated, magnetization change of the minute head run direction takes place to a bias layer, and reversal is considered for this magnetization fluctuation to get across to a head as a noise through a soft-magnetism layer.
[0020] Moreover, since the waves of a signal differ in the vertical recording layer and the bias layer, it thinks for having been generated as a complicated noise on a reproduction wave. This phenomenon poses especially a problem, when vertical recording thickness and a soft-magnetism layer are thin.
[0021] Since the pole area of a head is small, if distance leaves the magnetic field strength generated from a head, it will decrease rapidly and a directly big magnetic field will not join a bias layer. However, even in the soft-magnetism layer lower part, magnetization change of a soft-magnetism layer front face lets the switched connection force committed to the interface in that case pass, and is considered to cause reversal. Therefore, what is necessary is just to give an anisotropy to the extent that this is overcome to a bias layer. the bias magnetic field which this condition requires for a soft-magnetism layer -- xHcxMsbiasxtbias>MssoftxtsoftxHa=J to which the switched connection energy J of an interface is expressed [thickness / Ms and / coercive force / of tsoft and a bias film] as follows in the amount of saturation magnetization of Ha and a soft-magnetism layer when Hc and the amount of saturation magnetization are set to Msbias and thickness is set to tbias (1/2) -- it turns out that it is effective to heighten the coercive force of a bias layer or to thicken thickness of a bias layer from However, when thickness of a bias layer is thickened, magnetization distribution of a bias layer of what is lost lets a soft-magnetism layer pass, and flux reversal becomes remarkable [the problem that the noise which gets across to a head will increase].
[0022] This invention persons found out that it was required for the amount Mssoft of saturation magnetization of a soft-magnetism layer, and Thickness tsoft (nm) and the Msbias thickness tbias of a bias film (nm) to fill the relation expressed with the following formula, in order to avoid such a problem.
[0023] The sense of residual magnetization is the thickness which cannot change a lot, and the thickness of 40nm of a Mssoftx(tsoft-40nm) >Mssoftx40 nm+Msbiasxtbias soft-magnetism layer is a value decided by the exchange stiffness constant and anisotropy energy of a soft-magnetism layer. About 40nm can be considered mainly in the soft-magnetism layer using Co or Fe. The soft-magnetism layer separated from the bias layer from 40nm among soft magnetisms can intercept magnetization distribution, and can press down generating of a noise.
[0024] The coercive force Hc of a bias layer needs to satisfy the following relational expression.
[0025]
When Fe and Co are used for a Hc>2x(Mssoftxtsoft/Msxtbias) xHa soft-magnetism layer as a principal component and Co alloy is used for a bias layer, the bias magnetic field Ha is 29230. Since it is A/m, as coercive force Hc, it is 58460. The A/m grade is required. However, when what considering membranous Hc distribution is reversed by the smallest magnetic field to average Hc is taken into consideration, as membranous Hc, it is 160000 4 times as many as this. More than A/m is desirable.
[0026] Moreover, as a bias layer, the small thing of generating of a noise is good at the time of the saturation of magnetization. Moreover, it is effective for the magnetic particle not to necessarily be isolated like the magnetic-recording layer within a field, and to make it strong to heat fluctuation as a bias layer.
[0027] Hereafter, this invention is explained in detail with reference to a drawing.
[0028] Drawing 2 is a cross section showing the composition of the vertical-magnetic-recording medium of this invention.
[0029] So that it may illustrate this magnetic-recording medium 20 The soft-magnetism layer [7] 5 6 which consists of the nonmagnetic substrate [3] 1 2, for example, the seed layer which consists of NiAl, for example, the ground layer which consists of a chromium alloy, a cobalt alloy bias layer 4, for example, CoZrNb, or a FeCo system alloy layer, for example, the seed layer which consists of Ti, for example, the ground layer which consists of Ru, For example, it has the composition which carried out the laminating of the vertical-magnetic-recording layer 8 9 which consists of a CoCrPt system alloy or a CoPtCrO system alloy, for example, the protective layer which consists of C, and the lubricating layer 10 which consists of a perphloro polyether to order.
[0030] As a nonmagnetic substrate, a 2.5 inch chemical-strengthening alumino silica glass, glass ceramics, silicon, an aluminum containing alloy, carbon, a polyimide, polyester, etc. are used preferably, for example.
[0031] The seed layer 2 and the ground layer 3 are layers prepared arbitrarily if needed, in order to control the orientation of a bias layer, to lessen distribution and to arrange magnetization of a bias layer with ** on the other hand in a field with combination. NiAl, MgO, TiN, etc. can be used as a seed layer for this orientation control. Moreover, as

this ground layer, a chromium alloy, a vanadium alloy, a niobium alloy, a tantalum alloy, a tungsten alloy, etc. can be used.
[0032] Moreover, as a soft-magnetism layer 5, a CoZrNb alloy, a CoZrTa alloy, a CoFe alloy, a NiFe alloy, a FeAlSi alloy, a FeTaC alloy, a FeTaN alloy, etc. can be used, for example.
[0033] The seed layers 6 are arbitrary layers prepared if needed, and through the orientation of a ground layer, and particle-size control, they are prepared in order to control the orientation particle size of a vertical recording layer. Moreover, it is the arbitrary layers prepared if needed similarly, and the ground layer 7 is also formed in order to make detailed improvement of the perpendicular orientation of the vertical-magnetic-recording layer formed on it, and particle size.
[0034] As this seed layer 6, Ti, TiN, NiAl, etc. can be used, for example.
[0035] Moreover, as a ground layer 7, Ru, Hf, a nonmagnetic CoCr alloy, and Pt and Pd can be used, for example.
[0036] As a vertical-magnetic-recording layer 8, a CoCrPt system alloy or a CoPtCrO system alloy, a Co/Pt multilayer, a Co/Pd multilayer, a FePt ordered alloy, and a CoPt ordered alloy can be used.
[0037] A protective layer 9 and a lubricating layer 10 are also formed suitably if needed.
[0038] As a protective layer 9, spatter carbon and CVD carbon can be used, for example.
[0039] As a lubricating layer 10, a perfluoro polyether and the hydro fluoro ether can be used, for example. A lubricating layer is formed for example, by the dipping method, and can be formed.
[0040] An above-mentioned magnetic-recording medium is applicable to the following magnetic recorder and reproducing devices.
[0041] The perspective diagram which understood a part of example of the magnetic recorder and reproducing device which starts this invention at drawing 3 is shown.
[0042] The spindle 122 is equipped with the magnetic disk 121 of ****** for recording the information concerning this invention, and a rotation drive is carried out at a fixed rotational frequency by the spindle motor which is not illustrated. The slider 123 in which the magnetic head which accesses a magnetic disk 121 and performs informational record reproduction was carried is attached at the nose of cam of a suspension 124 which consists of sheet metal-like flat spring. The suspension 124 is connected to the end side of the arm 125 which has the bobbin section holding the drive coil which is not illustrated etc.
[0043] The voice coil motor 126 which is a kind of a linear motor is formed in the other end side of an arm 125. The voice coil motor 126 consists of a drive coil which was able to be wound up in the bobbin section of an arm 125 and which is not illustrated, and a magnetic circuit constituted with the permanent magnet and opposite yoke which have been countered and arranged so that it may be put.
[0044] An arm 125 is held by the ball bearing which was prepared in two upper and lower sides of the fixed shaft 127 and which is not illustrated, and a rotation rocking drive is carried out with a voice coil motor 126. That is, the position of the slider 123 on a magnetic disk 121 is controlled by the voice coil motor 126. In addition, 128 show the lid among drawing 2 .
[0045] An example is shown below and this invention is explained concretely.
[0046] The magnetic-recording medium 40 which has the same composition as example 1 drawing 2 was formed as follows.
[0047] First, the diameter chemical-strengthening alumino of 2.5 inch and the silica glass were prepared as a substrate 1. On the substrate 1, the NiAl alloy seed layer 2 was formed by the spatter. Then, the spatter of the ground layer 3 was carried out as a chromium alloy target. After forming the ground layer 3, coercive force is, and saturation magnetization Ms is the CoPt alloy bias layer 4 of 1200 (emu/cc) at the thickness of 80nm 160000 It became more than A/m, and the interaction between particles was strong and the spatter was carried out on conditions to which a remanence ratio becomes large.
[0048] The spatter of the soft-magnetism layer 5 which consists of a CoZrNb alloy of the saturation magnetization Ms of 1300 (emu/cc) was carried out by 180nm thickness.
[0049] Then, the spatter of the ground layer 7 with a thickness of 20nm was further carried out [the seed layer 6] for the rhenium respectively as a target by using Ti alloy as a target. Then, spatter formation of the 25nm was carried out for the CoPtCrO system vertical-magnetic-recording layer 8 by the oxygenation spatter using the 68at.%Co-20at.%Pt-12at.%Cr system target.
[0050] In addition, the spatter was altogether performed using DC magnetron sputtering.
[0051] Furthermore, the spatter of the protective coat 9 with a thickness of 7nm it is thin from carbon was carried out, the lubricating layer 10 which consists of a perphloro polyether was formed in the front face with the DIP coat, and the vertical-magnetic-recording medium 20 was obtained.
[0052] 790k with which the bias layer which has the anti-range of prices of 10msec order in radial can fully be saturated

using the magnetization jig only for [the obtained vertical-magnetic-recording medium 20] disks A/m The above pulse magnetic field was impressed and magnetization fixing was carried out to radial. When the voltage of 200V was impressed to the magnetization jig, it is 948k to radial. The magnetization more than A/m had started.

[0053] About this vertical-magnetic-recording medium, using the head which used 0.4m of width of recording track, and the GMR element of 90 micrometers of gap lengths for the single-pole magnetic pole of 0.6m of width of recording track, and reproduction for writing, first, write-in current was made to increase from 2mA to 50mA, and the solitary-wave form of 25kFCI was investigated. Consequently, the good square wave form without a big noise was shown. Then, although DC elimination was performed by 50mA and writing and DC elimination were again repeated with the optimal record current, neither increase of DC noise nor the changing wave shape was observed. About these media, medium S/N was measured by the frequency of 200MHz, and record frequency 520kFCI.

[0054] On the same conditions as this vertical-magnetic-recording medium, the disk formed to the soft-magnetism layer was fabricated, the magnetic-domain state of the soft-magnetism layer of this whole soft-magnetism layer sample front face was observed with the optical sir face ANAZA ether (OSA) using the Kerr effect, and the magnetic-domain structure of a soft-magnetism **** front face was investigated.

[0055] Moreover, the head which used 0.4m of width of recording track and the GMR element of 90 micrometers of gap lengths for the single-pole magnetic pole of 0.6m of width of recording track and reproduction for writing was used, and the spike-noise state of the obtained soft-magnetism layer sample was measured.

[0056] On the same conditions as this vertical-magnetic-recording medium, a VSM sample is started from the disk formed to the soft-magnetism layer, and it is the impression magnetic field +790 to the radial magnetization direction of a disk. The M-H magnetization curve was obtained for measurement of magnetization from A/m for the first time. The obtained result is shown in the graph 51 of drawing 4 . the ratio of the amount Mr of residual magnetization, and the amount Ms of saturation magnetization -- Mr/Ms has checked that they were 0.97 or more values 1580 After A/m impression, if a magnetic field is returned, since the amount of magnetization will return to a basis, 0.03 of 1-Mr/Ms which is the decrement of Mr is not because the reversal magnetic domain is formed, and is considered to be distribution to a circumferencial direction. At this time, it is 3950. From the bias magnetic field Hbias at the time of returning magnetization from A/m, the value erg [gamma= 0.82 / /] 2 estimated cm as binding energy. By the method of measuring radial residual magnetization, in the result which measured the fixing force of magnetization, also to magnetic field impression of 15800 A/m, moreover the fall of residual magnetization was not accepted, it impressed the magnetic field in the head run direction of a vertical-magnetic-recording medium, measured magnetization, and obtained the M-H magnetization curve. The obtained result is shown in the graph 52 of drawing 4 . 1000 or more values were acquired as ******** of the head run direction.

[0057] Hcbias created the sample which formed even the bias layer on the same conditions as a vertical-magnetic-recording medium, and measured this by asking for MH curve using VSM.

[0058] The bias magnetic field Hbias acquired as mentioned above, a Mssoftx(tsoft-40nm)/Mssoftx40 nm+Msbiasxtbias value, Mr/Ms, Hcbias, existence of a magnetic domain wall, generating of the spike noise by the repeat of record, and medium S/N are shown in the following tables 3 and 4.

[0059] The vertical-magnetic-recording medium was obtained like the example 1 except changing an example 2 or 14 soft-magnetism layer material, its thickness, Co content bias layer, its thickness, and vertical-magnetic-recording layer material, as shown in Tables 1 and 2.

[0060] In addition, the soft-magnetism layer sample which forms similarly even the soft-magnetism layer 5 in an example 6, and does not form the seed layer 6, the ground layer 7, the vertical-magnetic-recording layer 8, a protective coat 9, and a lubricating layer 10 was observed with the optical sir face ANAZA ether (OSA) using the Kerr effect, and the magnetic-domain structure of a soft-magnetism **** front face was investigated. The photograph view showing the investigated result is shown in drawing 5 . As shown in drawing 5 , it has checked that there was no generating of a magnetic domain on a soft-magnetism front face.

[0061] Moreover, the head which used 0.4m of width of recording track and the GMR element of 90 micrometers of gap lengths for the single-pole magnetic pole of 0.6m of width of recording track and reproduction for writing was used, and the noise state of the obtained soft-magnetism layer sample was measured. The result is shown in drawing 6 . As shown in drawing 6 , it has checked that a spike noise was not observed.

[0062] Moreover, the amount Mr of residual magnetization after impressing a magnetic field to the bias impression direction and a retrose at once and removing this about the sample started from the obtained vertical-magnetic-recording medium about the example 7 was measured. The graphical representation which expresses the relation between a magnetic field and the ratio of the amount of residual magnetization to the amount of initial residual magnetization to drawing 7 is shown.

[0063] The coercive force of a bias layer is 160000 so that it may illustrate. As a certain thing is shown in drawing 7

more than A/m, an impression magnetic field is 2370. A/m was found by that magnetization has the property of returning mostly.

[0064] The vertical-magnetic-recording medium was obtained like the example 1 except changing the example 1 of comparison or 19 soft-magnetism layer material, its thickness, Co content bias layer, its thickness, and vertical-magnetic-recording layer material, as shown in Tables 1 and 2. About the obtained vertical-magnetic-recording medium, the bias magnetic field Hbias, Mr/Ms, a Mssoftx(tsoft-40nm)/Mssoftx40 nm+Msbiasxtbias value, Mr/Ms, Hcbias, Hccritical, existence of a magnetic domain wall, generating of a spike noise, and the S/N value were investigated like the example 1. The obtained result is shown in the following tables 3 and 4.

[0065] About the example 1 of comparison, the magnetic-domain structure of a soft-magnetism **** front face as well as an example 6 was investigated. The photograph view showing the data based on OSA is shown in drawing 8 . It was checked that the magnetic domain wall which attains to a data area exists so that it might illustrate.

[0066] Moreover, the noise state was measured like the example 6 again. The result is shown in drawing 9 . It was checked that the spike noise under the influence of a magnetic domain wall has occurred so that it may illustrate.

[0067]

[Table 1]

	軟磁性膜			ハード膜			垂直記録層
	材料	Ms (emu/cc)	膜厚 (nm)	材料	Ms (emu/cc)	膜厚 (nm)	
比較例1	CoZrNb	1300	700	CoCrPtTaB	500	60	CoCrPt
比較例2	CoZrNb	1300	500	CoCrPtTaB	500	60	CoCrPt
比較例3	CoZrNb	1300	300	CoCrPtTaB	500	60	CoCrPt
比較例4	CoZrNb	1300	200	CoCrPtTaB	500	60	CoCrPt
実施例5	CoZrNb	1300	150	CoCrPtTaB	500	60	CoCrPt
実施例7	CoZrNb	1300	120	CoCrPtTaB	500	60	CoCrPt
比較例5	CoZrNb	1300	100	CoCrPtTaB	500	60	CoCrPt
比較例6	CoZrNb	1300	60	CoCrPtTaB	500	60	CoCrPt
比較例7	CoZrNb	1300	40	CoCrPtTaB	500	60	CoCrPt
比較例8	CoZrNb	1300	180	CoPt	1200	200	CoPtCrO
比較例9	CoZrNb	1300	180	CoPt	1200	150	CoPtCrO
実施例1	CoZrNb	1300	180	CoPt	1200	80	CoPtCrO
実施例2	CoZrNb	1300	180	CoPt	1200	60	CoPtCrO
比較例 10	CoZrNb	1300	150	CoCrPtTaB	500	250	CoCrPt
実施例3	CoZrNb	1300	150	CoCrPtTaB	500	120	CoCrPt
実施例4	CoZrNb	1300	150	CoCrPtTaB	500	80	CoCrPt
実施例5	CoZrNb	1300	150	CoCrPtTaB	500	60	CoCrPt
実施例6	CoZrNb	1300	150	CoCrPtTaB	500	40	CoCrPt

[0068]

[Table 2]

	軟磁性膜			ハード膜			垂直記録層
	材料	Ms (emu/cc)	膜厚 (nm)	材料	Ms (emu/cc)	膜厚 (nm)	
比較例 11	CoZrNb	1300	120	CoCrPtTaB	500	250	CoPtCrO
比較例 12	CoZrNb	1300	120	CoCrPtTaB	500	200	CoPtCrO
比較例 13	CoZrNb	1300	120	CoCrPtTaB	500	150	CoPtCrO
実施例7	CoZrNb	1300	120	CoCrPtTaB	500	60	CoPtCrO
実施例8	CoZrNb	1300	120	CoCrPtTaB	500	40	CoPtCrO
実施例9	CoZrNb	1300	180	Co	1200	80	CoPtCrB
実施例 10	CoZrNb	1300	180	CoPt	1200	80	CoPtCrB
比較例 14	Co90Fe10	1600	200	CoPtCrO	300	40	CoPtCrO
実施例 11	Co90Fe10	1600	150	CoPtCrO	300	40	CoPtCrO
実施例 12	Co90Fe10	1600	90	CoPtCrO	300	40	CoPtCrO
比較例 15	Co90Fe10	1600	90	CoPtCrO	300	120	CoPtCrO
比較例 16	Co90Fe10	1600	40	CoPtCrO	300	120	CoPtCrO
比較例 17	FeCoN	1800	200	CoCrPt	300	30	CoPtCrTa
実施例 13	FeCoN	1800	150	CoCrPt	300	30	CoPtCrTa
実施例 14	FeCoN	1800	120	CoCrPt	300	120	CoPtCrTa
比較例 18	FeCoN	1800	90	CoCrPt	300	120	CoPtCrTa
比較例 19	FeCoN	1800	40	CoCrPt	300	120	CoPtCrTa

[0069]
[Table 3]

	バイアス磁界H bias (A/m)	$Ms_{soft} \times (t_{softt}-40nm) / [Ms_{softt} \times 40nm + Ms_{bias} \times t_{bias}]$	Mr／Ms	Hc bias (A/m)	磁壁の存在の有無	スパイクノイズの発生	So p Nmr ms (dB)
比較例1	237	10.5	0.93	300200	×	—	36.5
比較例2	395	7.3	0.94	300200	×	—	36
比較例3	1185	4.1	0.96	300200	×	—	35.5
比較例4	2133	2.5	0.98	300200	○	無し	35.5
実施例5	3160	1.7	1	300200	◎	無し	36.5
実施例7	4740	1.3	0.99	300200	◎	無し	34.5
比較例5	6320	1.0	0.99	300200	◎	無し	28
比較例6	9480	0.3	0.99	300200	◎	無し	26
比較例7	6320	0.0	0.99	300200	◎	無し	25
比較例8	2370	0.6	0.95	221200	◎	無し	24.5
比較例9	2212	0.8	0.96	229100	◎	無し	25.5
実施例1	2765	1.2	0.98	237000	◎	無し	33.5
実施例2	3160	1.5	0.98	240950	◎	無し	34
比較例 10	3476	0.8	0.95	240950	◎	無し	26
実施例3	3476	1.3	0.97	268600	◎	無し	31.5
実施例4	3318	1.6	0.98	284400	◎	無し	32.5
実施例5	3160	1.7	1	300200	◎	無し	36.5
実施例6	3160	2.0	1	316000	◎	無し	36

[0070]
[Table 4]

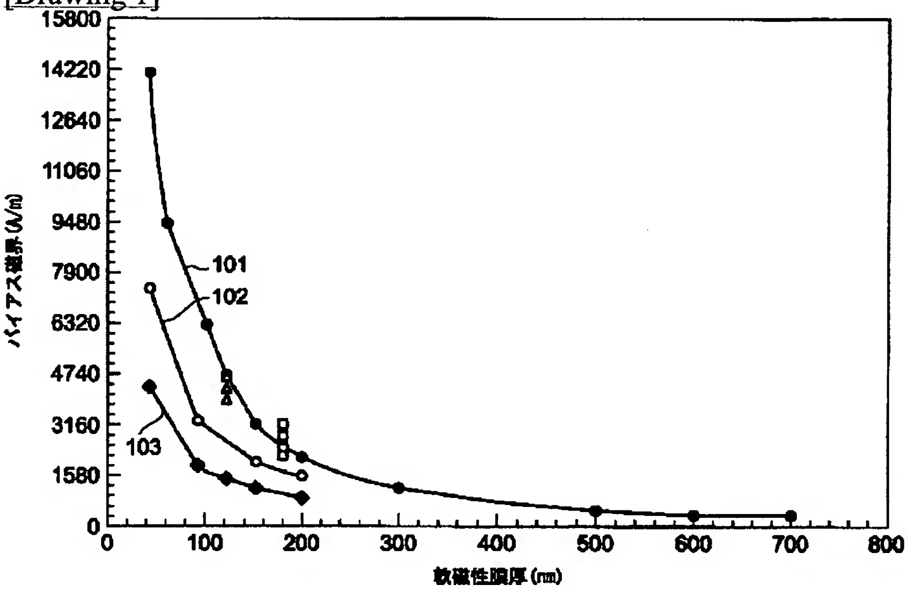
	バイアス磁界H bias (A/m)	Ms_{soft} × (t_{s} ft-40nm) ／[Ms_{softt} × 40nm＋ Ms_{bias} × t_{bias}]	Mr／Ms	Hc bias (A/m)	磁壁の存在の有無	スパイクノイズの発生	Soop Nmr ms (dB)
比較例 11	4740	0.6	0.96	248850	◎	無し	26.5
比較例 12	4345	0.7	0.98	248850	◎	無し	27
比較例 13	4345	0.8	0.97	252800	◎	無し	27.5
実施例7	4740	1.3	0.99	300200	◎	無し	34.5
実施例8	3950	1.4	1	316000	◎	無し	34
実施例9	3397	1.2	0.98	158000	◎	有り(大)	33.5
実施例 10	2686	1.2	0.98	221200	◎	有り(小)	33.5
比較例 14	1501	3.4	1	331800	×	−	34
実施例 11	1975	2.3	1	331800	◎	無し	35.5
実施例 12	3318	1.1	1	331800	◎	無し	35
比較例 15	3318	0.8	0.98	284400	◎	無し	25
比較例 16	7426	0.0	1	284400	◎	無し	20
比較例 17	869	3.6	1	252800	×	−	34
実施例 13	1185	2.4	1	252800	◎	無し	34
実施例 14	1501	1.3	0.99	244900	◎	無し	32
比較例 18	1975	0.8	0.98	229100	◎	有り(小)	24
比較例 19	4424	0.0	0.98	229100	◎	有り(小)	19

[0071] The magnetic domain which the example 1 of comparison or the thing of 3 has a weak bias magnetic field, is OSA measurement, and was generated from a disk periphery and inner circumference had spread even in the data area so that clearly from the above-mentioned table 3 or 4. Moreover, the spike noise was observed in the measurement using the head, and DC noise was also large as compared with the example.
[0072] In Mssoftx(tsoft-40nm) >Mssoftx40 nm+Msbiasxtbias, Soop/Nmrms>30dB and the good value were acquired by Medium SNR.
[0073] On the other hand, in Mssoftx(tsoft-40nm) <Mssoftx40 nm+Msbiasxtbias, Soop/Nmrms showed about 3dB of low values.
[0074] In the result which investigated the solitary-wave form of 25kFCI(s), soft-magnetism layer thickness showed the good square wave form without a big noise at the thing 200m or less. Then, although DC elimination was performed by 50mA and writing and DC elimination were again repeated with the optimal record current, neither increase of DC noise nor the changing wave shape was observed. However, the coercive force of a bias layer is 160000. When smaller [than A/m] and the same writing and same elimination were repeated by the maximum record of a head, there was a case where the noise of the small letter of a spike was seen at the time of DC elimination.
[0075] In addition, in the above-mentioned example, a soft-magnetism layer may be considered to be thickness with the bias film near a record layer and a record layer, and although the hard film of bias grant was a monostromatic and the bias film and the soft-magnetism layer were [every / a monostromatic], even if it makes this laminating composition, as long as a certain switched connection is working in between, in it, you may consider a bias film as total thickness.
[0076]
[Effect of the Invention] according to this invention, not making the whole disc data field generate a reverse magnetic domain, becoming possible to suppress spike-noise generating, and intercepting the noise from a bias layer effectively in a soft-magnetism layer by strengthening a bias magnetic field, -- since things are made, even if it repeats record reproduction, without magnetization declining, a signal is stable and a vertical-magnetic-recording medium with few noises is obtained by the external magnetic field

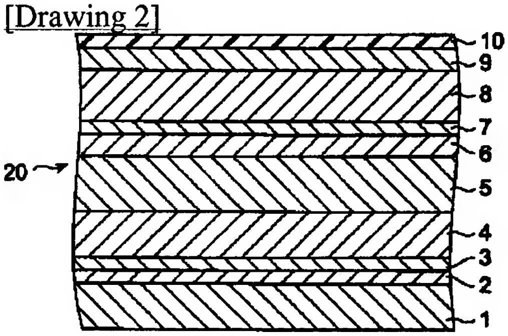
[Translation done.]

DRAWINGS

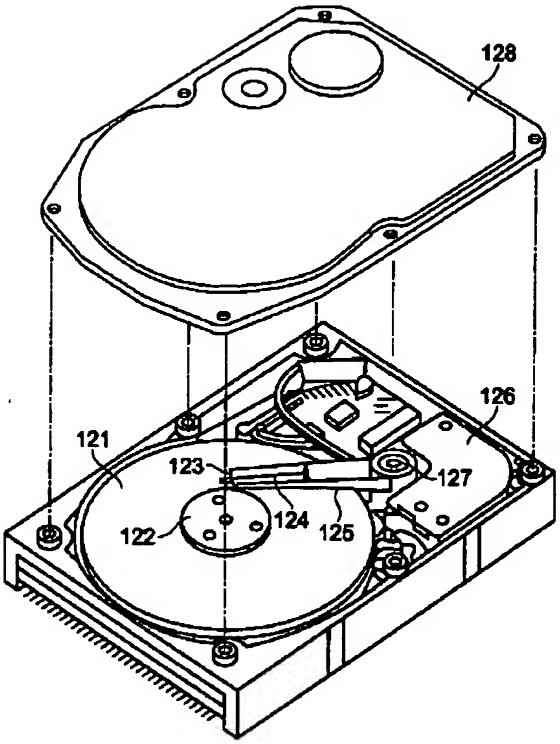
[Drawing 1]



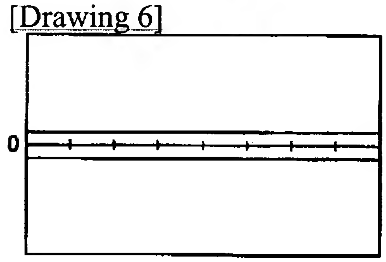
[Drawing 2]



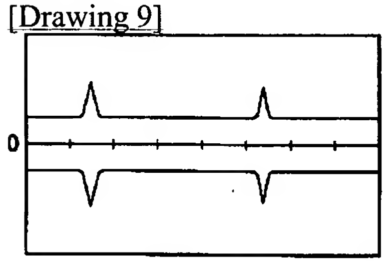
[Drawing 3]



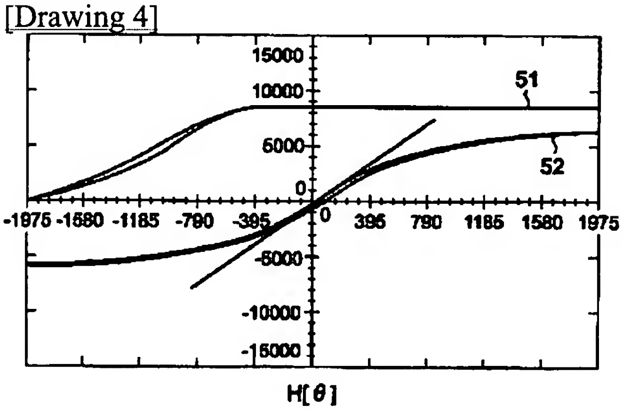
[Drawing 6]



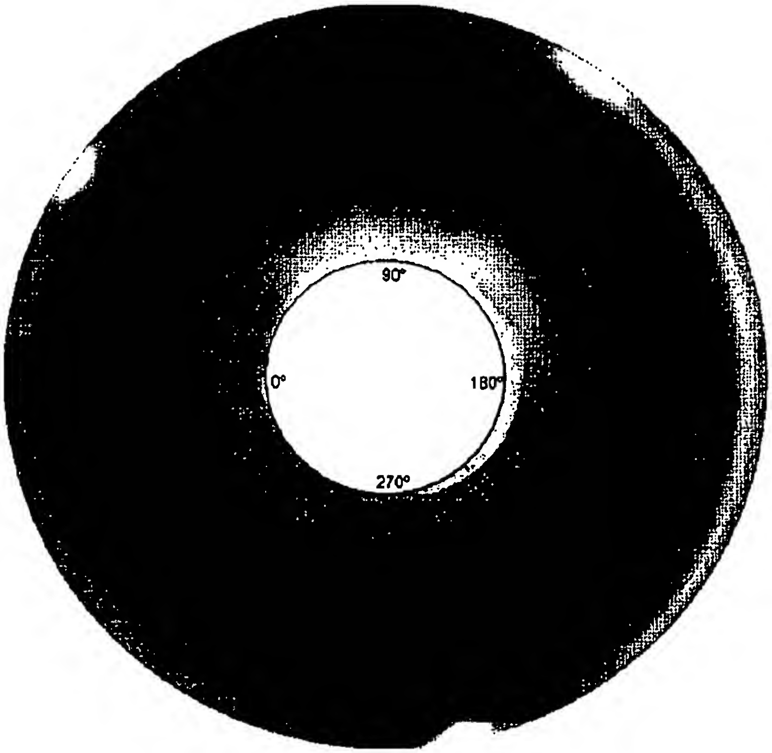
[Drawing 9]



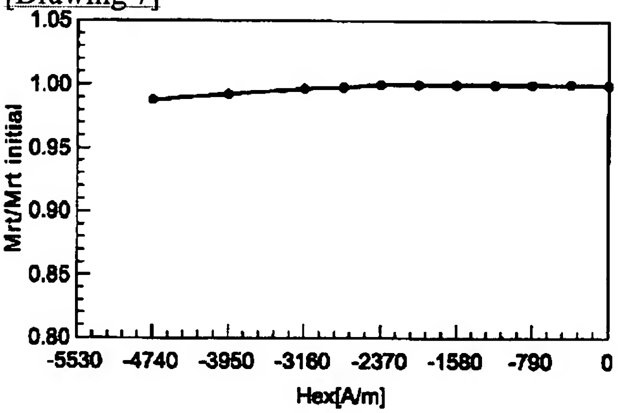
[Drawing 4]



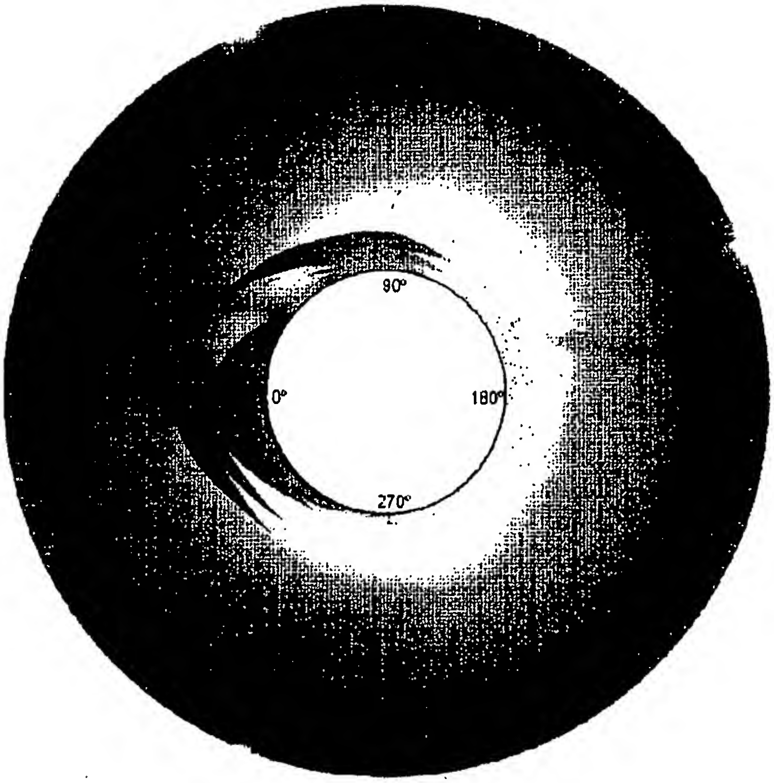
[Drawing 5]



[Drawing 7]



[Drawing 8]



[Translation done.]